

# HAWAIIAN SEISMIC EVENTS DURING 1969

By ROBERT Y. KOYANAGI and ELLIOT T. ENDO,  
 Hawaiian Volcano Observatory, Hawaii,  
 Menlo Park, Calif.

*Abstract.*—During 1969 the Hawaiian Volcano Observatory seismic net recorded 673 earthquakes of magnitudes 2.0 to 5.0 beneath Hawaii. Of this total, 119 were reported felt; 5 throughout the entire island of Hawaii. The overall pattern of seismicity remained the same as for recent years; the highest concentrations of earthquakes were in the volcanically active areas of southeastern Hawaii.

During 1969, the Hawaiian Volcano Observatory seismic net recorded 673 earthquakes of magnitude 2.0 to 5.0 (Richter scale) beneath Hawaii. Of these, 119 were felt; 5 throughout the entire island. Seismic activity during 1969, as in recent years, was concentrated beneath the southeastern part of the Hawaiian Ridge. This summary of seismic phenomena is the eighth compiled jointly by the U.S. Geological Survey's Hawaiian Volcano Observatory and National Center for Earthquake Research, Menlo Park, Calif. Earlier reports were by Koyanagi (1964, 1968, 1969a, b, c), Koyanagi and Endo (1965), and Koyanagi and Okamura (1966).

Earthquake hypocenters were calculated on the U.S. Geological Survey IBM 360/65 computer by means of the program HYPOLAYR (Eaton, 1969). Determinations of hypocenters were based on crustal model B of Eaton (1962), a layered model, and primarily on P-wave arrival times. S-wave arrival times were used to fix the origin times of some events that originated outside the seismic net. Arrival times were read to the nearest 0.05 second on the Develocorder film system (telemetered network) and to the nearest 0.1 second on the standard paper recorders. Of the 4,000 local events picked for study during 1969, 2,432 had epicenters with standard errors of less than 2.5 km in the latitude and longitude. The standard error in depth depends strongly on the number of stations available for the solution and on their location with respect to the epicenter. The error in depth is commonly comparable to that in epicenter position, but it can be much larger for unfavorably located epicenters. Earthquakes that occur at moderate distances outside the network have larger standard errors and have not been included in the plot of hypocenter and epicenter. Magnitudes were calculated from records from

several types of short-period seismographs, which have been related empirically to the standard Wood-Anderson seismograph at Hilo.

The distribution of well-located earthquakes larger than, or equal to, magnitude 2.0 in the vicinity of the island of Hawaii, southeasternmost in the Hawaiian archipelago (fig. 1), is shown for each quarter of the year (fig. 2). Events that occurred outside the map boundaries are listed in table 1.

The zone of concentrated seismic activity around the summit of Kilauea volcano is shown in detail in figures 3, 4,

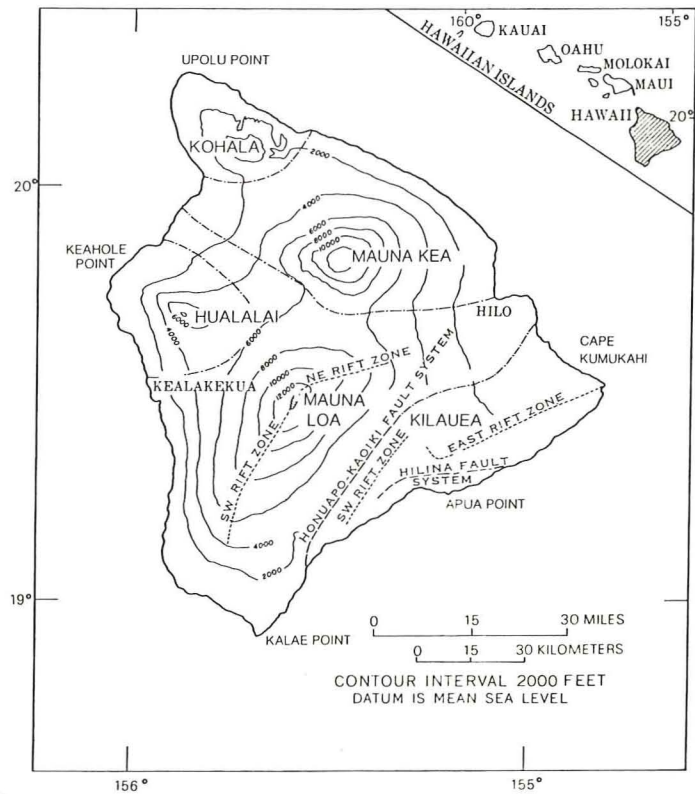


Figure 1.—Map of the island of Hawaii, showing the five volcanoes and their principal structural features. Dot-and-dash lines are boundaries of volcanic systems.

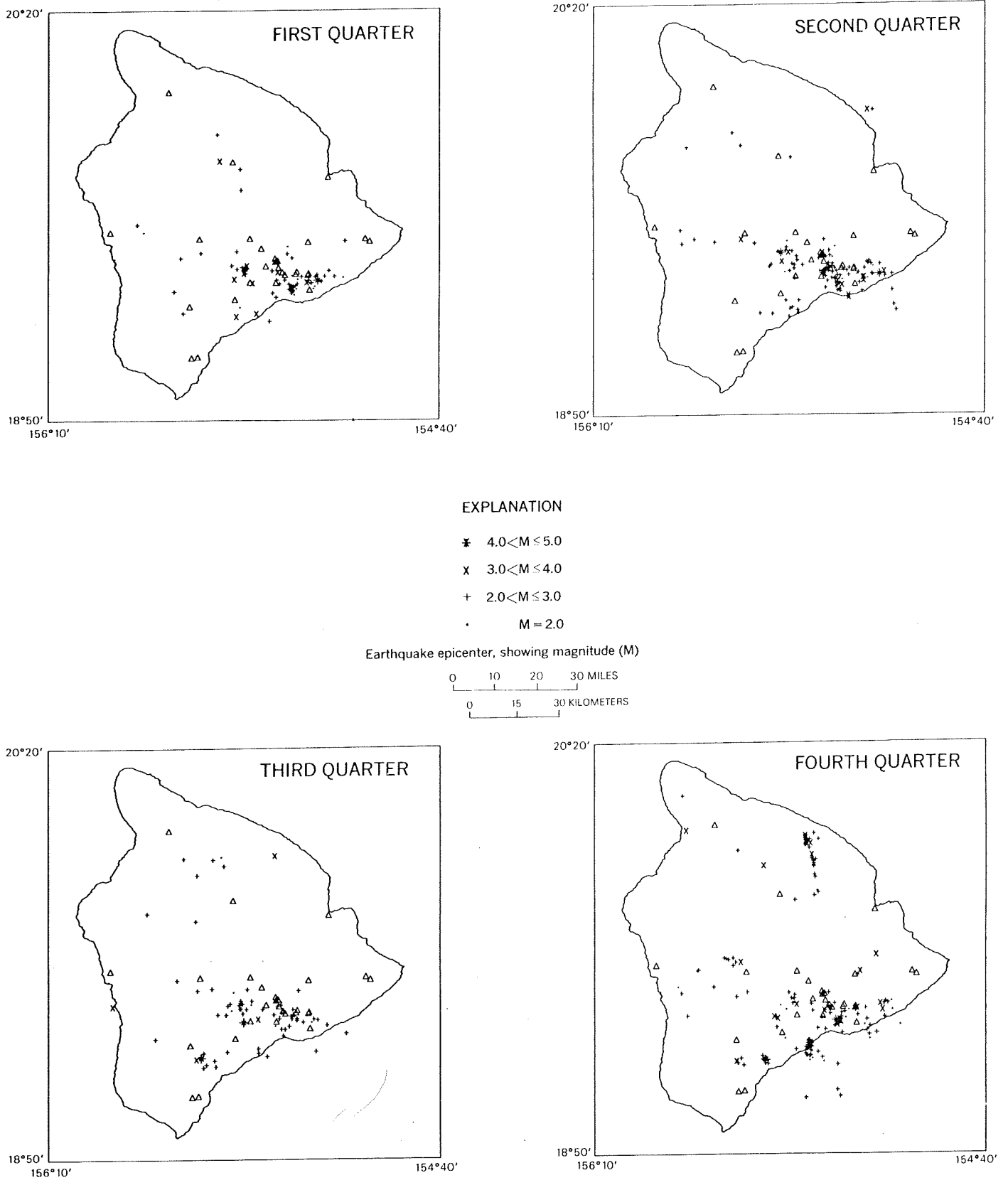


Figure 2.—Epicenters of earthquakes beneath or near the island of Hawaii during 1969. Earthquakes with magnitudes smaller than 2.0 or with standard errors of 2.5 km or greater in latitude or longitude are not included. Seismometer locations are indicated by open triangles.

Table 1.—Earthquakes of magnitude 2.0 or larger located off the quarterly epicenter maps

Date (1969)	Time <sup>1</sup>	Magni- tude	Depth (kilo- meters)	Epicenter coordinates	
				North latitude	West longitude
January	1 . . . . . 02-47-27.8	4.2	13	20°06'	157°52'
	28 . . . . . 10-44-19.1	2.0	13	20°52'	155°05'
February	3 . . . . . 01-15-47.3	2.9	13	19°37'	156°28'
	4 . . . . . 21-15-23.1	2.5	13	18°35'	156°01'
	10 . . . . . 10-55-08.0	2.5	31	20°10'	156°22'
	22 . . . . . 12-24-23.5	3.5	13	19°30'	156°20'
March	6 . . . . . 04-54-26.4	2.4	13	20°44'	156°06'
	13 . . . . . 00-21-32.7	2.8	13	19°19'	156°22'
	24 . . . . . 20-51-14.0	2.8	3	19°39'	156°22'
April	9 . . . . . 07-30-56.1	4.2	13	20°59'	155°43'
May	7 . . . . . 04-35-59.0	4.5	13	20°50'	155°21'
	7 . . . . . 04-48-33.5	2.2	13	20°50'	155°21'
	19 . . . . . 02-20-03.0	2.9	10	20°43.1'	155°33.1'
	22 . . . . . 05-25-08.5	2.6	59	20°23.7'	156°17.3'
	24 . . . . . 05-49-33.9	3.0	10	19°19.0'	156°34.7'
	28 . . . . . 20-20-12.9	2.9	10	20°06.3'	156°49.9'
	31 . . . . . 21-12-19.7	2.2	56	19°04.4'	154°41.1'
June	10 . . . . . 23-20-58.3	3.1	<sup>2</sup> 67?	18°49.8'	155°41.6'
	21 . . . . . 03-48-24.0	3.3	8	20°26'	156°50'
	26 . . . . . 15-24-58.4	3.1	10	20°29.9'	155°27.1'
	30 . . . . . 08-57-51.1	3.2	8	20°36'	154°54'
July	15 . . . . . 17-54-14.5	3.3	13	18°28'	156°48'
August	14 . . . . . 12-27-20.0	2.5	10	19°05.0'	156°43.4'
	30 . . . . . 14-27-11.3	2.9	10	19°38.3'	156°28.3'
September	2 . . . . . 05-06-22.0	3.3	10	19°34.9'	156°23.3'
	19 . . . . . 08-24-34.6	3.0	<sup>2</sup> 83?	19°42.0'	156°11.3'
October	3 . . . . . 19-25-56.2	2.8	22	18°49.0'	155°23.1'
	12 . . . . . 15-28-11.0	2.4	10	20°49.3'	156°04.6'
November	5 . . . . . 16-51-07.0	2.8	34	19°32.9'	156°18.8'
	16 . . . . . 07-06-37.2	2.2	10	20°17.0'	156°14.8'
	17 . . . . . 23-05-17.0	2.9	10	19°36.8'	156°31.6'
	24 . . . . . 09-44-09.1	2.7	45	19°43.4'	156°10.9'
	30 . . . . . 21-11-14.0	3.9	10	20°3/4°	162°
December	9 . . . . . 17-09-43.0	2.6	10	19°01.3'	154°43.3'
	17 . . . . . 19-42-25.3	3.1	13	19°03'	156°48'
	24 . . . . . 19-34-12.0	2.9	13	20°45'	154°54'

<sup>1</sup> Hawaiian standard time in hours, minutes, and seconds.

<sup>2</sup> Depth determinations for earthquakes deeper than 60 km are questionable.

and 5. Seismograph stations and the principal structural features of the region are illustrated in figure 3; all well-located earthquakes for the entire year are plotted on the same scale in figure 4; and all events in a 16-km-wide swath of concentrated activity trending south-southwestward through the Kilauea caldera are projected onto a cross section (*A-A'*, fig 3) in figure 5.

#### CHRONOLOGY OF SEISMIC ACTIVITY DURING 1969

The year 1969 showed an increase in the level of seismic activity as compared with 1968, and was characterized by frequent discontinuous volcanic eruptions from the upper east rift zone of Kilauea. Swarms of small earthquakes associated

with eruptions normally were confined to the outbreak area and to the area just south of the caldera that subsided during the eruptions. Such swarms generally were only a few kilometers deep. Between eruptive episodes, earthquakes were scattered over large areas adjacent to the eruptive centers and tended to occur at depths of about 10 km. Earthquakes associated with eruptions did not appear to exhibit the normal range in magnitude.

The flank eruption of February 22-28, 1969, and the flank eruption that started on May 24, 1969, and continued to the end of the year were characterized by sharp deflation of the summit, many shallow earthquakes, and continuous tremor. During both eruptions, phases of vigorous lava outpouring and strong tremor alternated with periods of degassing and weak tremor. The relation between the various types of seismic

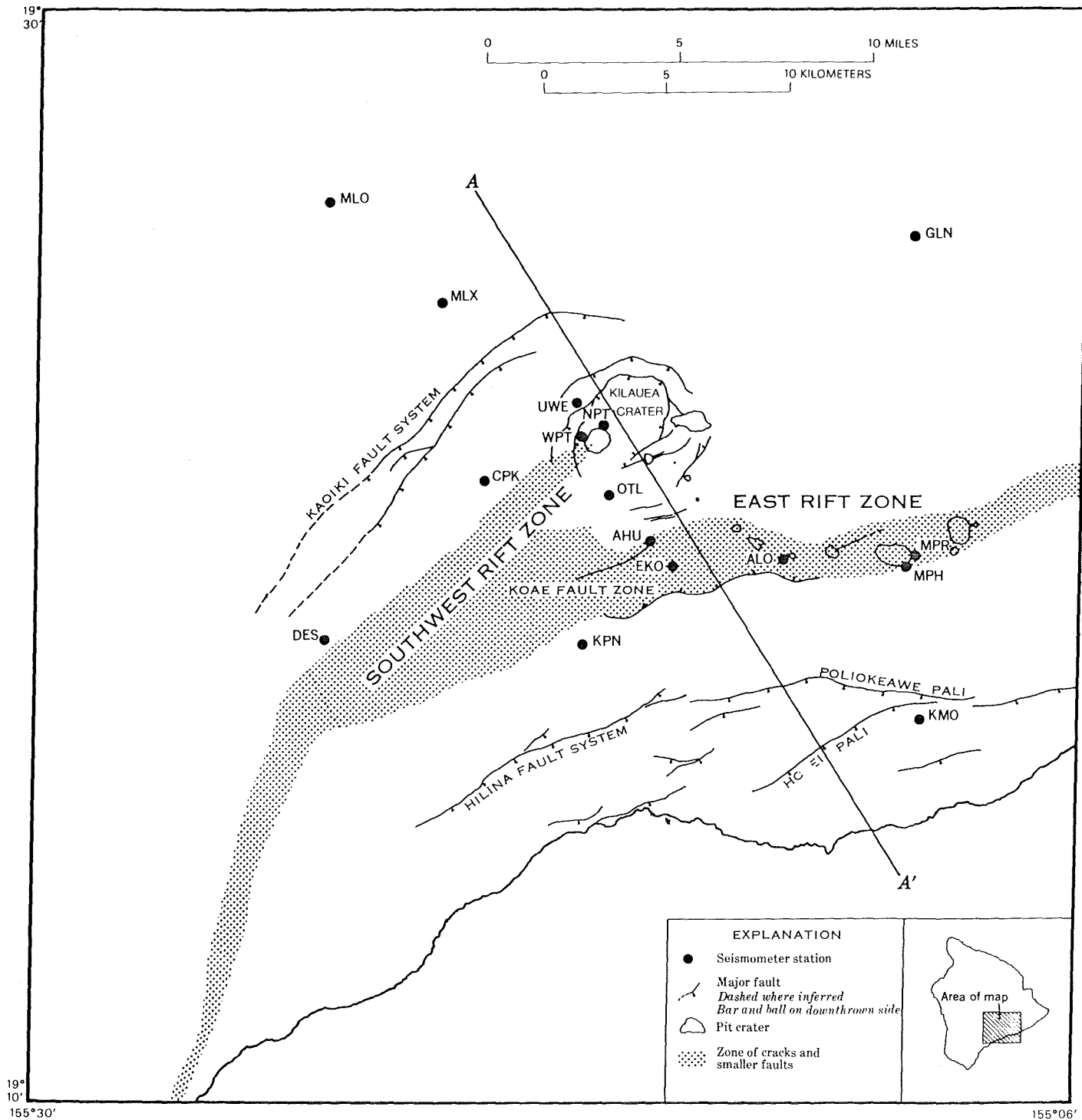


Figure 3.—Map of Kilauea summit region, showing geologic structures, seismometer locations, and cross section line A—A'. Geologic structures are after Stearns and Macdonald (1945), Peterson (1967), and Walker (1969).

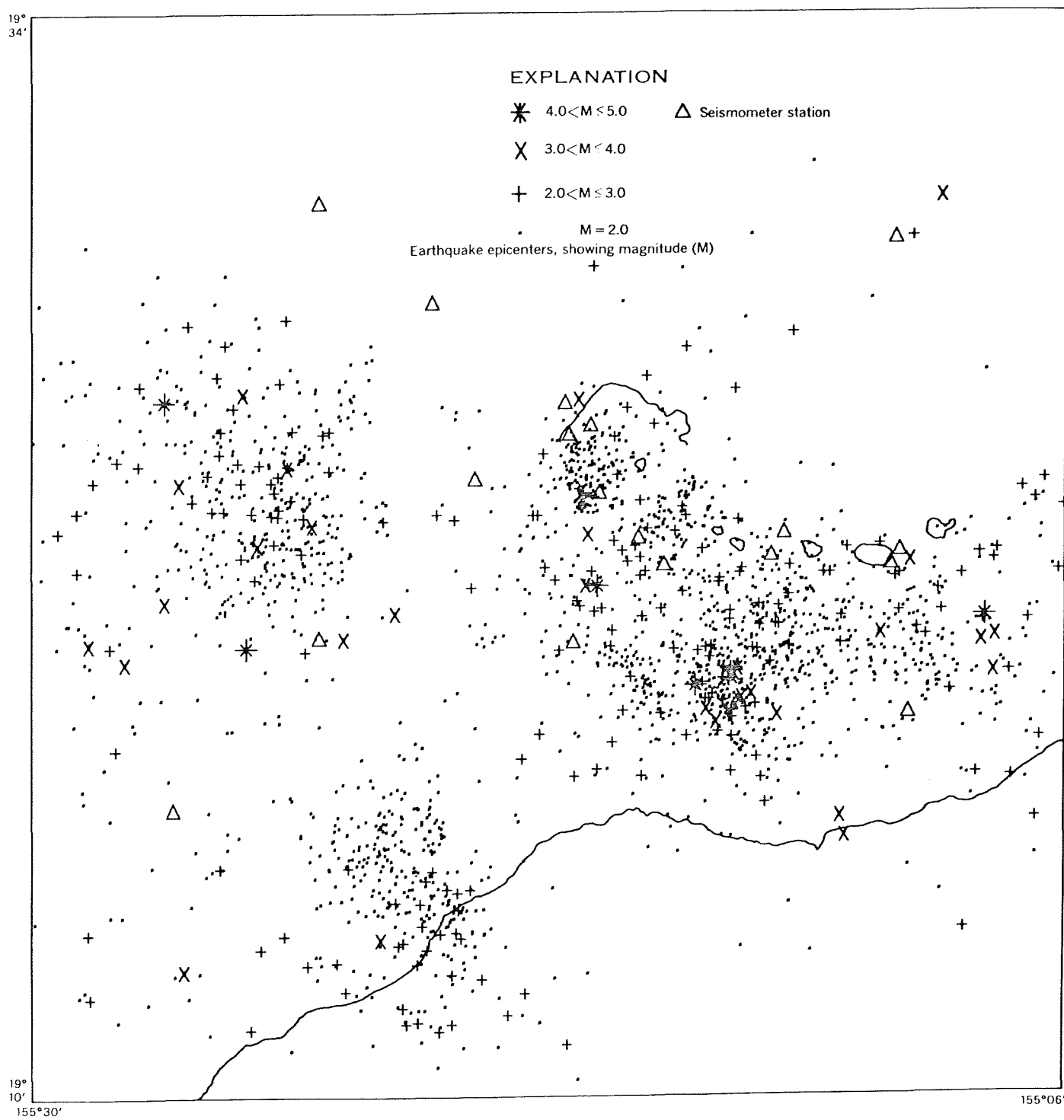


Figure 4.—Epicenters of earthquakes beneath the central part of Kilauea volcano and the adjacent southeast flank of Mauna Loa. All well-located epicenters with standard errors less than 2.5 km in latitude and longitude are included.

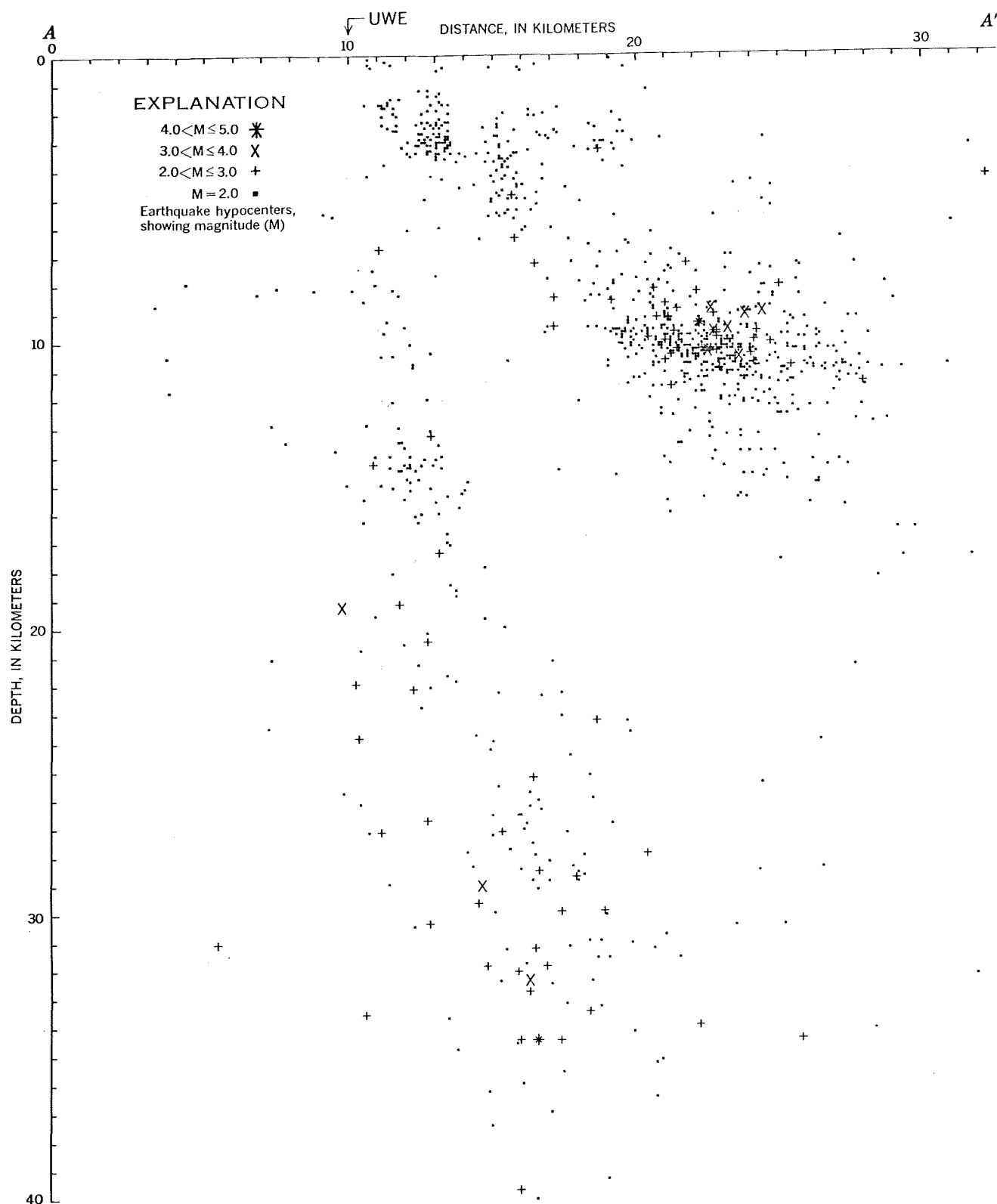


Figure 5.—Cross section along line A—A' produced by projecting all events within 8 km of the vertical plane through A—A' onto that plane. The sources of some of the families of earthquakes mentioned in the Hawaiian Volcano Observatory Quarterly Summaries can be identified on this cross section. Shallow caldera earthquakes are concentrated at depths of less than 5 km between 10 and 15 km along the profile, upper east rift, Koae, and Poliokeawe earthquakes are concentrated at depths near 10 km between 17 and 30 km along the profile, and 30-km south-summit earthquakes are distributed through the depth range 20 to 40 km between 10 and 23 km along the profile.

activity recorded and the style of the corresponding eruptive activity can be summarized as follows:

<i>Initial phase of eruption</i>	<i>Between phases of eruption</i>	<i>Secondary phases of eruption</i>
Summit deflation, shallow rift quakes, shallow caldera quakes. Lava fountains and strong tremor.	Summit inflation, weak tremor, "long-period" caldera quakes. Continued summit inflation, weak tremor near eruptive fissure, shallow caldera quakes.	Summit deflation, occasional shallow rift quakes, lava fountains, moderate tremor.

During the first half of the year, Kilauea earthquake activity was relatively high. Shallow caldera quakes averaged nearly 100 per day, and earthquakes beneath the southeast and southwest flanks of the volcano occurred at a rate of several tens per day. About two dozen of these were large enough to be felt. The largest earthquake of the year in Hawaii had a magnitude of 5.0 and was felt over the entire island. It originated about 20 km southeast of Kilauea caldera at 15:33<sup>1</sup> on May 9.

During the second half of the year, the frequency of Kilauea earthquakes remained at a moderate level. In addition to the flurries of small summit and southeast flank quakes that appeared to be associated with the activity of the erupting volcano, there were moderate concentrations of seismic activity in several other areas.

Late in September, activity picked up along the lower part of Kilauea's zone, about 20 km southwest of the summit. Between September 28 and October 16, 868 quakes were recorded; 310 occurred during the peak of activity on October 7-8. By November, seismicity about the southwest rift had declined considerably, and the center of activity shifted to the Mauna Kea region.

On the morning of November 5, residents along the northeast coast of the island reported that 14 earthquakes were felt. These earthquakes were the largest of a group that originated beneath the eastern flank of Mauna Kea at depths of 5 to 20 km. During the most intense period of activity, November 5-7, 30 earthquakes of magnitude 2.0 to 3.7 were recorded on the observatory seismographs. A smaller burst followed on November 10-11, and relative quiescence resumed thereafter. Only occasional shocks from this region were recorded during the rest of the year.

The number of deep quakes beneath the southeast flank of Mauna Loa increased during the second half of the year. These quakes originated at depths of 20-50 km and were characterized by relatively long periods (0.5 to 1.0 second) of their predominant waves.

SUMMARY

The seismic activity during 1969, as in recent years, was concentrated beneath the southeastern part of the Hawaiian

<sup>1</sup> All times are noted in Hawaiian standard time.

Ridge. Seventy-three percent of the quakes with magnitudes 2.0 to 5.0 were centered beneath active Kilauea and Mauna Loa volcanoes. Secondary centers were found beneath the flanks of Mauna Kea and off the west coast of the island of Hawaii. Focal depths were generally shallow, 0 to 10 km; the deep quakes were mostly from depths of 20 to 40 km beneath the south-summit area of Kilauea.

In 1969, 119 earthquakes were felt by residents of the island of Hawaii, 5 of the larger ones with magnitudes 3.7 to 5.0 islandwide. In the following table, the 673 events of magnitude 2.0 to 5.0 determined for the year are grouped to show their distribution according to magnitude and depth:

Magnitude	Depth (km)							
	<10	10-19	20-29	30-39	40-49	50-59	60-69	70-128
2.0-2.4 . . . .	195	119	19	34	4	1	...	2?
2.5-2.9 . . . .	103	59	11	14	6	3	1?	1?
3.0-3.4 . . . .	25	23	1	2	2	...	2?	1?
3.5-3.9 . . . .	12	12	1	5	1			
4.0-4.4 . . . .	3	5	...	2				
4.5-4.9 . . . .	1	1	...	1				
5.0 . . . . .	...	1						

NOTE.—Depth determinations for earthquakes deeper than 60 km are questionable.

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